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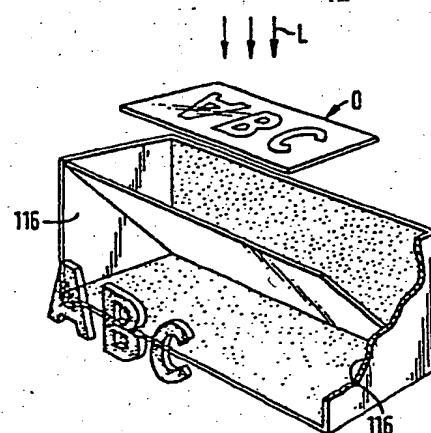
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(54) Title: REAL IMAGE PROJECTION DEVICE

(57) Abstract

An object has light reflected or emanating therefrom projected through a symmetrical imaging device. The symmetrical imaging device contains a reference plane where the light impinging thereon has its direction changed or altered. The symmetrical imaging device relative to the reference or symmetry plane has optical properties restricting the transmitted ray from the symmetrical imaging device to lay into a normal plane containing the incident ray and the normal to the reference plane at the point of incidence. The angle of incidence is equal to the angle of transmission, but is contained on the same side of the normal (where the angle of incidence is the angle between the incident light ray and normal, the angle of transmission is the angle between the reflected light ray and normal). In the retroreflecting aspect of this invention, each light ray is reflected precisely back upon itself before or after this light ray is specularly reflected by a partially transparent medium which surface is usually coinciding with the aforementioned reference plane. In the light deflection form of the invention that uses deflection or reflection or a combination of these aspects for transmission, here the device has a plane shape rather than a box shape and light from an object on one side of the device will be thrown to the opposite side of the device rather than sideways to the device in both cases. In either case, the light projected by the device forms images of objects in space. The image will be in precise symmetry with the object relative to the symmetry plane. In the deflecting aspect of the invention, the plane shape of the device is usually coinciding with the reference plane. The properties of the symmetrical imaging device about the reference plane differ from the law of reflection in that the angle of incidence and the angle of transmission are on the same side of the normal. Moreover, the produced image distinguishes from that conventionally produced by one lens or parabolic mirror because the distance between a reference plane relative to the symmetrical imaging device and object is equal to the distance between a reference plane relative to the symmetrical imaging device and image, when the reference plane is a straight flat plane. In the case of a retroreflecting device, light must be detoured as by a beam splitter, to produce a symmetrical image capable of having dimensional qualities. Various embodiments of the invention include schemes for shading the device from unwanted light, extending the viewing area, and projecting a plurality of images. Other embodiments include a prism structure for the device and arrangements of the device for achieving various special effects.



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REAL IMAGE PROJECTION DEVICE

This invention relates to real image projection devices and to symmetrical such devices.

Known devices do not constitute the reconstruction of light utilising the natural light rays and a symmetrical imaging device such as a reflecting screen or specialised rear projection screen.

SUMMARY OF THE INVENTION

The invention consists in a device for producing a viewable optical image of an object, the device having a notional reference surface and having the effect that, at said surface, light is transmitted through the surface and deflected according to the following laws: the incident ray at a point and the deflected ray are in the same plane as the normal, are equally inclined to the normal and are both on the same side of the normal.

An object has light reflected or emanating therefrom projected through a symmetrical imaging device. The symmetrical imaging device contains a reference plane where the light impinging thereon has its direction changed or altered. The symmetrical imaging device relative to the reference or symmetry plane has optical properties restricting the transmitted ray from the symmetrical imaging device to lay into a normal plane containing the incident ray and the normal to the reference plane at the point of

incidence. The angle of incidence is equal to the angle of transmission, but is contained on the same side of the normal (where the angle of incidence is the angle between the incident light ray and normal, the angle of transmission is the angle between the reflected light ray and normal). In the retroreflecting aspect of this invention, each light ray is reflected precisely back upon itself before or after this light ray is specularly reflected by a partially transparent medium which surface is usually coinciding with the aforementioned reference plane. In the light deflection form of the invention that uses deflection or reflection of a combination of these aspects for transmission, here the device has a plane shape rather than a box shape and light from an object on one side of the device will be thrown to the opposite side of the device rather than sideways to the device in both cases. In either case, the light projected by the device forms images of objects in space. The image will be in precise symmetry with the object relative to the symmetry plane. In the deflecting aspect of the invention, the plane shape of the device is usually coinciding with the reference plane. The properties of the symmetrical imaging device about the reference plane differ from the law of reflection in that the angle of incidence and the angle of transmission are on the same side of the normal. Moreover, the produced image distinguishes from that conventionally produced by one lens or parabolic mirror because the distance between a reference plane relative to the symmetrical imaging device and object is equal to the distance between a reference plane relative to the symmetrical imaging device and image, when the reference plane is a straight flat plane. In the case of a retroreflecting device, light must be detoured as by a beam splitter, to produce a symmetrical image capable of having dimensional qualities. Various embodiments of the invention include schemes for shading the

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device from unwanted light, extending the viewing area, and projecting a plurality of images. Other embodiments include a prism structure for the device and arrangements of the device for achieving various special effects.

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OTHER OBJECTS, FEATURES AND ADVANTAGES

An object of this invention is to disclose the projection of an image utilising the reflected light from an object such as that seen in the real world. According to this aspect of the invention, the object is conventionally
10 illuminated, for example either by front illumination in the case of an opaque object or by rear illumination in the case of a translucent object. Light from the object is projected through a symmetrical imaging device. The symmetrical
15 imaging device has a reference plane where light incident upon the device has its direction changed and the light with changed direction is transmitted from the device. All points on the reference plane are active over the surface of the reference plane in accordance with the following rule.

The symmetrical imaging device relative to the
20 reference plane has optical properties restricting the transmitted ray from the symmetrical imaging device to a normal plane containing the incident ray and the normal to the reference plane to the point of incidence. The angle of incidence is equal to the angle of transmission but is con-
25 tained on the same side of the normal (where the angle of incidence is the angle between the incident light ray and a normal and the angle of transmission is the angle between the reflected light ray and a normal).

Images from objects projected further apart from
30 the device than the object versus distance to the device will also become visible and appear to be reversed left-right and upsidedown.

Other than for viewing or projecting images, the devices can be used for the multiple functions usually

performed by lenses and parabolic mirrors.

A further object of this invention is to disclose a screen for transmitting from one side of the screen an image of an object to the opposite side of the screen. This is previously called the deflective form of the device. In this aspect of the invention, the image from the device is a precise reciprocal of the object projected by the device. For example, an image of what is essentially a convex human contour would appear reciprocally as an image of a concave human contour.

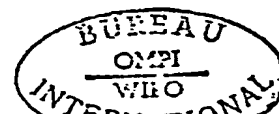
An advantage of this invention is that the image, unlike that produced through a positive spherical lens or parabolic mirror, is at the same distance from the retro-imaging device as the object when the image is reflected from the reference plane. Thus, by increasing the distance of the object from the retroimaging device, one can increase the distance from the image and retroimaging device. For example, utilising this invention a three-dimensional reciprocal image of an object can be easily cast out into the street through a storefront window.

A further advantage is that by using reciprocal objects, one can cast an image of a real world object.

For example, by imaging the concave features of the human mask, one can image with reverse parity the exterior of a human face.

A further function of one part of this invention is to adapt a beam splitter to a retroreflecting screen to the casting of such images. According to this aspect of the invention, the beam splitter is placed at an angle between an illuminated object and a retroreflecting screen. Light impinging upon the beam splitter from the retroreflecting screen is detoured outwardly and away from the screen path back to the object. Being so detoured, a reciprocal image is formed. The formed reciprocal image may then be viewed

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as being real, and out in space in front of the viewer.

A further object of this invention is to provide a shade on an opposite side of the beam splitter from the retroreflector. An advantage of using the shade is the blocking of virtual images of the environment from transmission to a viewer of the formed image.

Additionally, the shade may comprise a louvre screen having angular elements and being placed in the light path. In addition to blocking transmission of virtual images of the environment, the louvred screen reduces visibility of the object itself, as opposed to the projected image of the object. A further object of the present invention is to include a partially absorptive screen on the viewing side of the beam splitter. An advantage of this arrangement is reduction of wash-out due to light from the viewing side entering the device. Such object may be accomplished by forming the screen from a light polarising filter or a colour filter.

An additional advantage of this arrangement may be seen by including a louvre screen at the point where light enters the device from the object and at the point where light leaves the device to form the projected image. In this arrangement, the louvred screen is also placed proximate to the retroreflector surface. An advantage of this arrangement is the reduction of wash-out due to the excessive object light and/or ambient light striking the retroreflector at non-transmissive angles that would interfere with the image being projected.

Another object of the present invention is to provide special effects by combining an imaged object with a non-imaged object. The non-imaged object may be a flat two-dimensional object or it may be a solid object held in the image viewing area. The advantages of such arrangement are increased versatility. Since it is contemplated that



the invention will often find applications in commercial settings, the user of the invention is afforded a wide variety of "eye-catching" options.

A further object of the present invention is to
5 provide a device with as wide a viewing area as possible for the projected image. In keeping with this object, specular elements such as mirrors or retroreflectors may be placed at either side of the beam splitter. Such improvements in view area will add to a brighter image in the case that the
10 device is used for non-aerial projection such as on a diffuse screen or in electronic image recording. Additionally, the retroreflector may be extended to the sides of the beam splitter and/or curved inwardly to extend the viewing angle. The viewing range may also be extended by adding
15 additional retroreflectors. An advantage of this extended viewing range is self-apparent: the wider the viewing range, the longer the projected image is available for viewing by its intended audience.

Still another object of the present invention is
20 to provide a plurality of beam splitters such that the image is projected at a plurality of locations. Thus, the image may be formed at a series of locations or in a circular display. An advantage of this arrangement is using one device to form several images for viewing at more than one
25 location by more than one viewer.

Still another object of this invention is to provide a transparent medium between the beam splitter and the retroreflector such as a prism or a fluid filled prism. The properties of a prism are: they bend light and the
30 medium of which the prism is constructed may have an index of refraction greater than that of air. Thus, a more efficient device may be constructed. Further advantages of this arrangement include simplicity of construction for less expense and with increased versatility. For example, the

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retroreflector could be a series of cube corners formed integrally with the prism or it could be a curved surface. Furthermore, the surfaces of the medium could be coded or scrambled to reduce distortion due to interference of light.

5 Still another object of the present invention is to provide a beam splitter that is movable within the light path for spacially moving projected image. An advantage of this arrangement is the addition of motion to the image. By moving the beam splitter, the image appears to be drifting
10 in and out as the beam splitter moves toward and away from the object.

A further object of the present is to provide a retroreflector having light openings by which the pattern of the light openings in the retroreflector forms the image to
15 be projected. One advantage of this approach is that viewing area of the image is increased. By using interchangeable retroreflectors having varying light opening patterns, a versatile display is possible. A further advantage of this aspect of the present invention is that
20 dated material or material of periodically changing nature may be readily substituted in the device for that which was previously there.

Additionally, another object of the invention is to provide a device for imaging electronic displays. In
25 this application, the present light imaging device is interfaced to an electronic display, such as a cathode ray tube. The image formed on the screen of the cathode ray tube is then projected through the device and forms an image in the imaging area of the device. Possible advantages of
30 this system would be to add three dimensions to a moving image or to add a greater sense of depth to an image. A further advantage is to bring an optical image (such as from a television) closer to a viewer without loss of viewing area.

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Another object of the present invention is to provide a beam splitter having a series of silver dots with dark backing on a glass substrate. Such a beam splitter has the properties of being reflective on one side and non-reflective on the other side; the beam splitter is transmissive through both sides. Such a beam splitter improves the efficiency of the present invention.

Other objects, features and advantages of this invention will become more apparent after referring to the following specification and attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1A is a three-dimensional view of the projection device in this invention utilising a retro-reflecting screen and beam splitter to create a reciprocal image of the letters "ABC";

Fig. 1B is a side perspective view of Fig. 1A illustrating the property of the invention whereby the image is thrown some distance from the projection device;

Fig. 2 is an embodiment of this invention similar to Fig. 1, the embodiment therein illustrating a retroprojection device, which retroprojection device throws the reciprocal of the letters to a new location;

Figs. 3A - 3C are all embodiments of specialised screens which can be used with the embodiment of Fig. 2; and

Fig. 4 is an embodiment of the invention wherein two symmetrical imaging devices are used so as to project the image of the object (leftmost face) appears the same as the object;

Fig. 5 is a schematic of an embodiment of the invention wherein various shading and interference reducing components may be interchanged to suit the device to various applications;

Fig. 6A is a schematic of a beam splitter having a louvred screen for preventing interference due to unwanted

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light;

Fig. 6B is a schematic showing a pair of louvred screens provided in the object area and image viewing area for preventing interference due to unwanted light;

5 Fig. 6C is a schematic of an embodiment of the invention showing a louvred screen proximate to a retro-reflector surface for eliminating interference due to unwanted light;

10 Fig. 7 is a schematic of an embodiment of the invention wherein a solid object is placed in the imaging area;

Fig. 8 is a schematic of an embodiment of the invention showing a curved retroreflector for extending the angle of visibility of the formed image; and showing a
15 pattern of light openings in a retroreflector as an object to be imaged;

Fig. 9 is a schematic of an embodiment of the invention wherein a series of beam splitters are used to form a series of images from one object;

20 Fig. 10 is a perspective view of an embodiment of the invention wherein two prisms guide object light rays to form the projected image;

Fig. 11A is a perspective view of an embodiment of the invention having a pair of prisms with a curved retro-
25 reflector/prism interface;

Fig. 11B is a perspective view of an embodiment of the invention showing fluted or scrambled object and image forming surfaces on a device comprised of two prisms;

30 Fig. 12 is a schematic of an embodiment of the invention showing a curved or movable beam splitter for creating a distorted or pulsing image from a stationary object;

Fig. 13 is a perspective view from an edge of a beam splitting mirror having a reflective metallic dot

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matrix and a dull coating on the reflective matrix such that one side of the beam splitter is reflective, the other side is not reflecting, and both sides are transmissive.

Referring to Fig. 1A, an object O is illuminated
5 by a light source L which light source is only schematically shown. In the view of Fig. 1A, the object happens to be transparent or translucent. The light thus can be projected from the rear thereof.

Referring to the view of Fig. 1B, the light from
10 the object passes to a retroreflecting screen 20 mounted on the base of a three-sided box 22. Light from the retro-reflecting screen returns directly to the object O.

As those having skill in the art know, a retro-reflecting screen returns the light impinging upon it with
15 the precise angularity as the light is received from an object. Thus, and assuming no beam splitter 24 intermediate the object O and retroreflecting screen 20, one would expect that the light would reflect back upon and enhance precisely with a real image the real world object O.

20 Interposition of the beam splitter 24 at a preferred 45 degree angle changes this. Specifically, the beam splitter causes at least some of the converging light to be detoured to an image plane I. At the image plane I the image of the object (here shown as the letters "ABC") is
25 recreated. As the image is recreated, a viewer having a perspective from a solid angle of projection equal to the solid angle of projection of the retroreflecting screen and the beam splitter can see the letters ABC projected in space. Similarly it can be cast on a screen or be recorded.

30 In actual fact, the retroreflecting screen could be mounted on the end of wall 26 of the box 22. However, in this location a viewer of the image I such as that schematically shown by the eye 30 would in Fig. 1B have a bright and illuminated background against which to view the image.



As a bright and illuminated background would detract from the intensity of the image, it is usually preferred to mount the retroreflecting screen 22 so that the viewer has light passed to his view with a relatively dark background.

5 Typically end wall 26 is painted with a dark, light absorptive coating such as non-glossy black paint and the like.

It is also important to distinguish this invention from that of the conventional law of reflection. Taking the case of a retroimaging screen, it will be understood that
10 the screen has a theoretical reference plane in which light changes its direction. This screen has optical properties restricting the transmitting ray to the retroreflecting screen to a normal plane containing the incident ray and the normal to the reference plane within the screen at the point
15 of incidence. The angle of incident is equal to the angle of transmission, but is contained on the same side of the normal. The angle of incidence is defined as the angle between the incident light ray and a normal and the angle of transmission or reflection is defined as the angle between
20 the reflected ray and a normal.

It is important to distinguish this projection system from that of a conventional lens. Specifically, in the case of a lens, a reciprocal image moves. Where the object is far away, the image moves to the focal point of
25 the lens. Conversely, where the object approaches the focal length of the lens, the image is projected at increasing distances. A reciprocal relationship results.

Here, between the image and the object there is a direct relationship. Specifically, the relationship is that
30 the object to symmetry imaging device distance will always remain the same as the image to symmetry imaging device distance. When the symmetry of plane is chosen to be non-reflecting, e.g. by use of curved beam splitter, or by use of a curved rear deflector, the image will be deformed



according to the same rules of symmetry.

This latter rule produces on images some effects which are not immediately apparent. Take, for instance, the image of a human face. Typically, the nose of a human face will be closer to the projection screen than the ears of the human face.

The projection of a reciprocal image will give an opposite result. Specifically, the human image will have the nose closer to the projection device than the ears.

10 Thus, images projected by the device will be reciprocal. It will be as if one is viewing a mask from the inside.

An expedient to correct this reversal of distance parity is to utilise for the object a mask. Thereafter, the projected image will be a real life image.

15 As will hereinafter be briefly discussed, and in the case of stereoscopic projection, it is necessary to reverse the right-left parity to prevent pseudoscopic images.

Having discussed an embodiment of this invention utilising a retroreflecting screen, attention now can be given to the projection of an image using retroprojection devices such as illustrated in Figs. 3A, 3B and 3C. This will first be discussed with respect to Fig. 2.

25 Referring to Fig. 2, a light source L, illuminates an object O, in the form of letters ABC deflective re a projection. A device P is illustrated. The property of device P is exactly similar to that of the retroreflecting
30 screen 22. Specifically, reflected or emanating light will diverge from each point on object O, (letters ABC). It will impinge upon the screen device P. Light will be projected from the screen device P, converging to an image I of the
35 letters ABC in the same, exact and identical angularity as light projected from the letters ABC onto the screen device P. There results projected in space a reciprocal image of

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the letters ABC.

The construction of the projection device P can take several forms, which forms can all be easily understood with reference to Figs. 3A, 3B or 3C.

5 Referring to Fig. 3A, a device P, is shown consisting of glass bead lenses 40 aligned in a matrix 41 on one side of screen 60 and glass bead lenses 50 aligned in a matrix 51 on the opposite side of screen 60. A rear pro-
10 jection screen 60 sits intermediate the lens matrixes 41, 51.

The resulting projection system is easy to understand. Specifically, light from all angles is imaged through matrix 41 onto the rear projection screen 60. At
15 the rear projection screen 60, the light is then seen by the matrix of lenses 51 and each individual lens 50 causes light to emanate from the rear side of the rear projection screen 60 with the exact same and precise angularity as the light was received. There will result a recreation of the images
20 as described.

The same effect can be produced using pinholes. A device utilising pinholes is illustrated in Fig. 3B.

In Fig. 3B, a rear projection screen 60 is shown having a series of individual pinholes 42 aligned in a
25 matrix 43. Conversely and at the opposite side there are pinholes 52 aligned in a matrix 53. The result is the same. Specifically, light enters and forms an image on the rear projection screen 60. This image is seen at each of the pinholes with the light exiting through the pinholes. The
30 angularity assigned to an outgoing ray is the reciprocal of the light to an incoming ray. Therefore, an image can be formed in the manner illustrated in Fig. 2.

It will be apparent that if matrices differ in size, enlargement is possible. Therefore, it is mentioned
35 that the idea must be interpreted as wide as possible.

Referring to Fig. 3C, yet another embodiment is illustrated. In particular, a matrix of positive spherical lenses 61 is illustrated. Each lens is aligned between paired pinholes 44 towards the object and 54 towards the image. As before, these respective lenses 61, pinholes 44, 54 are aligned in respective matrices, 45, 55.

It will be seen that the separation between the matrix of pinholes 45 and the matrix of pinholes 55 is chosen to be the exact focal length of each of the lenses 61 of the lens matrix 65. With this property, the light rays pass along the illustrated path and each entering light ray enters with an angle equal and opposite to each exiting light ray. Again, the screen illustrated in Fig. 3C will produce a symmetry imaging characteristic such as that previously illustrated.

Reviewing the device of Figs. 3A, 3B and 3C, again it can be seen how the generic definition of symmetrical imaging devices aptly describe their function. Each device has a plane where the light changes direction. The symmetrical imaging device relative to its reference plane has optical properties restricting the transmitted ray from the symmetrical imaging device to a normal plane containing the incident ray and the normal to the reference plane at the point of incidence. The angle of incidence is equal to the angle of transmission, but is contained on the same side of the normal. The angle of incidence is the angle between the incident light ray and the normal and the angle of transmission is the angle between the transmitted ray and a normal. Where transmission of a light image of the object occurs from one side of the device to the opposite side of the device, it will be seen that there results an image.

It will be seen and realised that the images created are not those conventionally created by spherical lenses. Moreover, the image is to be distinguished from any



illuminated object merely placed in front of a retro-reflecting screen. Where an illuminated object is placed in front of a retrorreflecting screen, an image of that object is cast right back precisely upon the object itself. Here
5 and in this invention, the image of the object must be cast somewhere other than back upon the object itself. It is the realisation that the image exists that is one of the important aspects of this invention.

Referring to Fig. 4, a symmetrical imaging device
10 for transmitting an image is shown. An object O, here in the form of the human face, is placed on one side of a first transmission device T_1 . It casts a reciprocal image in the form of a mask M on the opposite side thereof. The image of
15 mask M is then taken by a second image transmission device T_2 . This image transmission device forms an image of the human face at I.

It can be seen that with the above-described
20 reciprocal imaging device, the image of the face may be reproduced. It is seen that as the object O is moved toward the right, the image I will also move toward the right. Further, both object and image will move at the same speed.

I have just finished illustrating with respect to
25 Fig. 4 two symmetrical imaging devices wherein an image from an object on one side of the device is relayed to the opposite side. This image is in turn re-relayed by a second symmetrical imaging device to produce a real parity image. Those having skill in the art will realise that the retro-
30 reflecting scheme that I have illustrated with respect to Figs. 1A and 1B could as well be used twice to restore parity to the image.

Referring now to Fig. 5, various design options
resulting in different device characteristics for different
35 applications are described. The device may have a pair of retroreflectors at locations 70 and 73 in Figs. With two

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retroreflectors gathering and reflecting light, the image will appear brighter.

Ambient light may be a problem; unwanted object light may also be a problem. Various placements of 5 different components are available for alleviating this problem. In Fig. 5 location 70 may be a shade for blocking environmental or ambient light that may interfere with the image from behind. Alternatively, a shade may be located at position 73.

10 Referring to Fig. 6A, a louvred screen 74 is placed in proximity to beam splitter 75. Object light strikes retroreflector 77 and is projected to form an image I. An advantage of this arrangement is that unwanted light from behind or above is blocked by the louvres and not 15 passed through the beam splitter to the retroreflector 77.

Light from the front and from behind in the image forming area may be rejected by interposition of a screen 72 (Fig. 5) made of a partially absorptive material. The screen may be a light polarising filter to reject light not 20 of the desired polarity. Additional polarising filters may be included to achieve cross-polarisation. By adding the screen, the floating or three-dimensional effect of the image is lost if the screen is placed in the image forming area. If the screen is placed before the image forming 25 area, it must have properties such that it will transmit the image. In this case, wash-out due to light from the viewer's side of the beam splitter is diminished.

Fig. 6B shows an arrangement of louvred screens 78 and 79. Light from the object O is reflected from beam 30 splitter 81 to retroreflector 80. The light from the object O also passes through the beam splitter to retroreflector 82, the image is formed at I. In this arrangement the object cannot be directly viewed and does not interfere with the projected image. Alternatively, location 80 or 82 could

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be a shade.

Louvred screens 78 and 79 reject unwanted ambient light. Louvred screen 78 rejects unwanted light from above and behind the screen; screen 79 rejects light from above and in front of the image. Thus, wash-out and degradation of the image is diminished.

In Fig. 6C a retroreflector 85 has been fitted with a louvred screen arrangement 86. An object O casts light upon the retroreflector 85 which light is reflected to form an image I by beam splitter 84. Light from the rear is shaded by shade 83. The louvres 86 reject unwanted object or ambient light that may strike the retroreflector 85 at an angle not conducive to proper transmission from the beam splitter 84 to the imaging area. Thus, interference from object or ambient light is prevented.

In a commercial setting, various optical deceptions may prove to be of an attention-getting nature. Referring to Fig. 5 location 70 could be a two-dimensional object that is clearly visible in the image viewing area. Thus, when object O is projected to form image I, the image will appear to float in front of a two-dimensional object displayed on 70. For example, the two-dimensional object formed on 70 could be a background with the image I projecting out of said background. Alternatively, the object could be placed on beam splitter 71.

Alternatively, a three-dimensional object could be placed in the image viewing area. Thus, in Fig. 7 letters "A" and "C" are projected as image I. The letter "B" is a solid object suspended in the image viewing area. A person reaching out to touch the objects would not be able to touch the "A" or the "C", but would be able to touch the "B". One possible application might be to project an image behind the object suspended in the image viewing area. When the object is removed for inspection, the image of the object is

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projected in the object's place so that the object appears to still be in the place from which it was removed. The extra objects may enhance a visual reference.

It is desirable to have the object viewed from as wide an angle as possible such that as many persons may view it at one time from as many different directions as possible. To this end, specular elements may be placed at either end of the beam splitter in the device. These elements may include end mirrors or retroreflectors 116 (Fig. 1A). Also a lens-like or prism type set of deflectors can be used without distorting the so produced image if they are placed symmetrically about the beam splitter. Alternatively, the viewing range may be extended by providing for an inwardly curved retroreflector 90 (Fig. 8).

Another novel embodiment of the present invention is shown in Fig. 9. An object O is reflected from beam splitters 92, 93, 94 onto retroreflector 91. Retroreflector 91 projects the image through the beam splitters to form a series of images I in the image viewing area. One wholly distinct and separate image is formed for each beam splitter. Thus, a series of images may be displayed alongside one another, one of which may be the object. Alternatively, the images may be projected circularly by arranging the beam splitters in a radial fashion. Additionally, the beam splitters may be arranged such that the object may be projected in all directions such that the object is viewable from all angles.

Up to this point the discussion has centred on imaging devices using air as a medium of transmission. It is possible to interpose a transparent medium between the beam splitter and the retroreflector, the medium having an index of refraction higher than that of air. In this way, the light rays would be guided along the light path from the object to the image.



One way to accomplish transmission through a transparent medium would be to use a prism arrangement (Figs. 10 and 11). Operation of the device using a prism as a transmission medium would be as with other configurations. Referring to Fig. 10, an object O is placed before the double prism configuration. Light entering the upper prism P₁ from the object is retroreflected by retroreflecting surfaces 96. Beam splitter 95 projects the image. Light entering lower prism P₂ is reflected off of retroreflectors 97 and is projected as image off of a lower portion of beam splitter 95. The images converge in the image viewing area forming perceived image I.

An advantage of using prisms is that the device may be made in one solid piece. In this way, greater accuracy is achieved at an increase economy of manufacture.

There is occasionally specular interference at the interface of the prism medium with the retroreflectors. The retroreflectors may be formed from triple mirror cube corners and may be mounted integrally with the prism. By using triple mirror cube corners specular interference is eliminated. Alternatively, a curved retroreflector 98 may be used (Fig. 11) such that specular rays resulting from reflection at the retroreflector and prism interface are focussed at infinity.

For large devices and prism arrays, the configuration of Fig. 10 may be made of plastic or glass with a hollow interior. The interior may be filled by any light conducting fluid, such as: water, other liquids, or certain light conductive gases.

Fig. 11B shows another embodiment of the prism imaging device. In this embodiment, object O reflects light rays through scrambled surfaces 102 on the object side of the prism. These light rays are reflected from beam splitter 105 to retroreflector 104. There they are



projected through scrambled surfaces 103 to form image I. Scrambled surfaces 102 and 103 are aligned in such a way that only image-forming light is projected through the device to form image I. Ambient or environmental light interference, as well as object light interference, are eliminated or distorted.

Fig. 12 shows an object O, retroreflectors 107 and 108, and an image I. Beam splitter 106 is of a design such that it may be mechanically or otherwise moved in and out. In this way, the object is brought closer to and further from the beam splitter 106. Since this is a symmetrical device, the formed image appears to move further and closer when viewed by a viewer, and image motion is suggested.

Another variation of the embodiment shown in Fig. 12 is to bend the beam splitter 106 or otherwise distort it. In this way, the object O forms a distorted image I. This may result in a "fun-house mirror effect" or an increase or reduction in image size depending on the distortion introduced into the beam splitters.

It is possible to form a pattern in the retro-reflector surface for admitting light into the imaging device as is shown in Fig. 8. Thus, light admitted through the object O in Fig. 8 is reflected from beam splitter 110 to retroreflecting surface 90 and thence to form image I in the image viewing area. If the light openings have angularity, view angle is enhanced and direct object visibility is diminished.

An advantage of this embodiment of this invention is the possibility of interchanging the message displayed by the device. Thus, dated or periodically changed information (such as movie marquee information), may be kept current with great economy and ease of operation.

It is possible to replace the object in any of the aforementioned embodiments of the invention with an

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electronic display, such as the cathode ray tube. In this way, a moving or electronic object may be projected to the image viewing area. Such an arrangement would give a three-dimensional effect to otherwise flat moving scenes.

5 The symmetrical imaging device does not require external electronic components or lasers to operate; it is readily attached to an electronic display without complicated interfacing. Such an application would produce a colour-correct projected image having little or no distortion.

10 In certain embodiments of the invention, the beam splitter is a perforated mirror, which mirror is a novel and unique development integral to the development of this invention. Referring to Fig. 13, the mirror 112 is formed on a sheet of glass 113 or other such light transmissive
15 medium. A matrix of reflective dots 114 is formed on one surface of the glass. The matrix may be formed from silver or other such reflective metals or materials. The back of the reflective material may be coated with a non-reflective
20 image). The resulting "perforated mirror" has the characteristics of being light transmissive in both directions and light reflective in only one direction. Such a mirror is ideally suited for applications involving the symmetrical imaging device.

25 The beam splitter may consist of uncoated transparent material such as pure glass. There may be light openings in the retroreflector (or matrix of these) to transmit light between the interior of the device and the environment.

30 For example, Fig. 14 is a diagrammatic sectional view of four alternative arrangements of beam splitter and retroreflector with light openings. Fig. 14 shows a sheet-shaped imaging device with retroreflectors 90 (having retroreflective material 194) and light openings 92 and a

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beam splitter 24. A preferred angular placement of the light openings will provide a high clarity in one viewing direction and simultaneous reduction of direct object visibility. Ideally, the retro-areas and light openings are made of small enough size to remain individually unnoticed to the viewer. Each of these embodiments in Fig. 14 can be provided as sheet-like embodiment as can the apparatus shown in each of Figs. 3A, 3B, 3C and then has the same effect as the box-like embodiments such as shown in Fig. 1A. Thus each embodiment contemplated in Fig. 14 can be embodied as a sheet-like Fresnel version of a box-like arrangement and the other box-like arrangements can be treated similarly. To reduce spurious images and/or improve contrast, a mask 196 or louvre may be used and/or a reverse light path used to that shown or the device rotated to make beam splitter 24 vertical so that a spurious image (or light directly from the object) is too high or too low to be viewed.

The following features are of particular interest:

- (a) masking shades, e.g. to cut down ambient light, (b) louvred or directed screens to cut down ambient light, spurious images and direct viewing of the original object, (c) absorptive surfaces, e.g. to cut down spurious images, and (d) intergrating the image and further objects in the viewing area either by light openings forming a stencil object cut-out of the retroreflective material or by a stencil object laid on the beam splitter. These features (a), (b), (c), (d) may also be considered as individual inventions in their own right, as also may be considered (e) a louvre with at least one side made retroreflecting, (f) a beam splitter comprising a sheet of transparent material coated with an intermittent specularly reflecting coating, e.g. of spots, stripes or matrix, which may have a light absorptive backing, and (g) a beam splitter having graded reflectivity, e.g. graded from the centre to the periphery.

These various features may be used to contribute to improved contrast and/or reduction of interference, e.g. from ambient light in the object space, image space or elsewhere and from direct viewing of the object or spurious light paths from the object.

The invention may also be considered as not limited to the inclusion of the illuminated object and/or the observer.

It is to be noted that the light is not a focussed image at the beam splitter or at the retroreflector and therefore these can be interrupted (not continuous) and/or the retroreflector need not be directed. Also, the angle between the beam splitter and the retroreflector can usefully be substantially less than 45° , e.g. 20° to 35° , preferably about 30° as shown in Fig. 15, which is a section through a device embodying the invention in the form of a box having a reduced height.

If the retroreflector (e.g. 90, Fig. 8) is extended to meet (e.g. the edges of) the beam splitter (24, Fig. 8), the viewing area (i.e. the angular spread over which the image can be properly viewed) is substantially increased.

In Fig. 1 and similar embodiments, there is better contrast (with reflected ambient light) the lower the reflectivity of beam splitter 24, though there is lower image intensity; an optimum figure below 50% can be found by experiment. If the absorptive and retroreflective surfaces 20, 26 are interchanged, there is better contrast the higher the reflectivity of the beam splitter 24, though again with lower image intensity; an optimum figure above 50% can be found by experiment. It is to be noted that in these two cases the retroreflector would be respectively on the image and object sides of the beam splitter.

The "matrix of retroreflectors" referred to above,

may comprise small individual corner-cube or bead reflectors, each being a retroreflector.

In Fig. 5, the device further comprises a partially absorptive screen placed on a viewing side of said beam splitter such that light from the viewer's side of the beam splitter will pass through the screen twice and image-forming light will pass through the screen once so that wash-out of the image due to light from the viewer's side will be diminished.

10 In Fig. 11A said transparent medium have a curved boundary interface or surface to focus and/or deflect specular rays resulting from reflection at that surface or interface. The focus may not be at infinity. The curved surface may not be at the interface with the retroreflector.

15 If, in Fig. 7, instead of illuminating the object O, this is left in shadow and an illuminated background member placed above it, this constitutes means to provide an illuminated background for a non-illuminated object whereby the device will appear to form an orthoscopic shadow image
20 (i.e. one without back to front reversal) of the object.

The image is normally pseudoscopic (i.e. with back to front reversal because of the back to front symmetry of the device which, for example, causes any object point to produce an image point an equal distance from the notional
25 reference surface when a plane beam splitter is used). If this poses a problem, the device is arranged to process light from the object at least twice to produce back to front reversal of the image a corresponding number of times in succession as exemplified in Fig. 4 or the device is
30 arranged for light from the object to fall at least twice on at least one of the beam splitters and the retroreflector matrix to produce back to front reversal of the image a corresponding number of times as exemplified in Fig. 16 with reflection at mirror 198, or again there may be used at

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least one more beam splitter arranged such that light from an object falls onto a first said beam splitter and then onto a second said beam splitter to form an image in an image viewing area, which may be exemplified as use of a device corresponding to two devices as shown in Fig. 1A used in tandem. Fig. 9 illustrates a case in which, instead, said first and second beam splitters are used so that respective images are formed in an image viewing area.

There may, of course, be used a plurality of any of the features described or illustrated and any combination of any such features.

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CLAIMS

1. A device for producing a viewable optical image of an object, the device having a notional reference surface and having the effect that, at said surface, light
5 is transmitted through the surface and deflected according to the following laws: the incident ray at a point and the deflected ray are in the same plane as the normal, are equally inclined to the normal and are both on the same side of the normal.
- 10 2. A symmetrical imaging device for projecting an image of an illuminated object at a pre-selected distance from said imaging device, said symmetrical imaging device comprising in combination: a matrix of retroreflectors for reflecting light rays from said illuminated object impinging
15 on said retroreflectors back toward the object in an opposite direction along a same light path as said rays travelled toward said retroreflectors; a beam splitter in said light path for projecting said image at a place other than said object.
- 20 3. The device of claim 2, comprising a plurality of matrices of retroreflectors.
4. The device of claim 2 or 3, further comprising a shade disposed on an opposite side of said beam splitter from said retroreflectors for blocking virtual images of the
25 environment from transmission to a viewer.
5. The device of any one of claims 2 to 4, comprising a louvre screen with angular elements placed in said light path proximate to said beam splitter on an opposite side of said beam splitter from said retroreflectors or
30 blocking virtual images of the environment from transmission to a viewer and for reducing visibility of said object, as opposed to said image, through the device.
6. The device of any one of claims 2 to 5, further comprising a partially absorptive screen placed on a

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viewing side of said beam splitter such that light from the viewer's side of the beam splitter will pass through the screen twice and image-forming light will pass through the screen once so that wash-out of the image due to light from the viewer's side will be diminished.

7. The device of claim 6, wherein the partially absorptive screen is a light polarising filter.

8. The device of any one of claims 2 to 7 comprising: direction selective surfaces proximate to an object area and to an image-forming area and having similar light transmission angles for reducing object visibility through the device and for diminishing wash-out due to ambient light from the viewer's side of the beam splitter and excess object light.

9. The device of any one of claims 2 to 8, comprising: a louvre screen with its angular elements placed in said light path proximate to said retroreflector to reduce wash-out due to excessive ambient and object light.

10. The device of any one of claims 2 to 9, comprising: means for combining imaged and non-imaged objects in an image viewing area.

11. The device of any one of claims 2 to 10, further comprising: means for positioning a solid object in the image viewing area.

12. The device of any one of claims 2 to 11 comprising: means for extending the viewing area of said image.

13. The device of claim 12, wherein said viewing area extending means comprises two deflecting elements placed symmetrically at two sides of the beam splitter.

14. The device of claim 13, wherein said deflecting elements comprise mirrors.

15. The device of claim 13 or 14, wherein said deflecting elements comprise retroreflectors.

16. The device of claim 13, 14 or 15, wherein said deflecting elements comprise prisms.

17. The device of any one of claims 12 to 16, wherein said viewing area extending means comprises an inwardly curved retroreflector on a side of the beam splitter that is opposite from the image viewing area.

18. The device of any one of claims 2 to 17, comprising: a plurality of beam splitters in said light path for projecting said image for viewing at a plurality of places other than said object.

19. The device of any one of claims 2 to 18, comprising: a transparent medium between said beam splitter and said retroreflector having index of refraction higher than that of air, for guiding said light rays along said light path from said object to said image.

20. The device of claim 10, wherein the transparent medium comprises a fluid.

21. The device of claim 19 or 20, wherein the transparent medium comprises a prism.

22. The device of claim 19 or 20, wherein the transparent medium comprises a plurality of prisms.

23. The device of claim 22, wherein said prisms include scrambler surfaces proximate to said object and said image viewing area for reducing the intensity of visible secondary images resulting from reflection at a medium-retroreflector interface.

24. The device of any one of claims 19 to 23, wherein said retroreflector comprises triple mirror cube corners integral with said transparent medium.

25. The device of any one of claims 19 to 24, wherein said transparent medium has a curved boundary interface or surface to focus and/or deflect specular rays resulting from reflection at that surface or interface.

26. The device of any one of claims 2 to 25,

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comprising: a source of object illumination.

27. The device of any one of claims 2 to 26, comprising: means to provide an illuminated background for a non-illuminated object whereby the device will appear to form an orthoscopic shadow image (i.e. one without back to front reversal) of the object.

28. The device of any one of claims 2 to 27, wherein said beam splitter is operably movable within the light path for spatially moving said projected image.

10 29. The device of any one of claims 2 to 28, wherein said beam splitter is distorted for projecting a distorted image.

30. The device of any one of claims 2 to 29, wherein said image is formed on a translucent screen.

15 31. The device of any one of claims 2 to 30, wherein said image is formed from an object comprising a pattern of light openings in said retroreflectors.

32. The device of any one of claims 2 to 31, wherein the illuminated object is an electronic display.

20 33. The device of any one of claims 2 to 32, arranged to process light from the object at least twice to produce back to front reversal of the image a corresponding number of times in succession.

34. The device of any one of claims 2 to 33, arranged for light from the object to fall at least twice on at least one of the beam splitter and the retroreflector matrix to produce back to front reversal of the image a corresponding number of times.

30 35. The device of any one of claims 2 to 34, comprising at least one more beam splitter arranged such that light from an object falls onto a first said beam splitter and then onto a second said beam splitter to form an image in an image viewing area.

36. The device of any one of claims 2 to 34,

comprising at least one more beam splitter arranged such that light from an object falls onto a first said beam splitter and then onto a second said beam splitter for form respective images in an image viewing area.

5 37. The device of any one of claims 2 to 36, wherein the beam splitter reflects more than 50% of the light incident thereon and the retroreflector is on the object side thereof.

10 38. The device of any one of claims 2 to 36, wherein the beam splitter reflects less than 50% of the light incident thereon and the retroreflector is on the image side thereof.

15 39. The device of any one of claims 2 to 36, wherein the beam splitter consists of uncoated transparent glass.

40. The device of any one of claims 2 to 38, wherein the beam splitter has distinct areas for transmission and specular reflection, comprising: a plate of glass having a light reflective metallic dot pattern.

20 41. The device of claim 40, wherein said dot pattern has a light-absorptive backing.

42. The device of any one of claims 2 to 41, comprising a retroreflector with light gaps to pass light from the object to the image.

25 43. The device of claim 42, the retroreflector having louvred form.

44. The device of any one of claims 2 to 43, having an angle substantially less than 45° between the beam splitter and the retroreflector and having reduced height.

30 45. The device of any one of claims 2 to 44, in which the retroreflector extends to meet the beam splitter.

46. The device of any one of claims 2 to 45, wherein the beam splitter comprises a sheet of transparent material coated with an intermittent specularly reflecting



coating.

47. The device of claim 46, in which the reflecting coating has a light-absorptive backing.

48. The device of any one of claims 2 to 47, wherein the beam splitter has graded reflectivity.

49. The device of claim 48, wherein the beam splitter has reflectivity graded from the centre to the periphery.

50. The device of claim 1, in combination with the features recited in any one or more of claims 10, 11, 12, 26, 27, 30, 32 and 33.

51. The device of claim 1 or 50, comprising directed shade means.

52. The device of claim 1 or 50, comprising louvre means.

53. The device of claim 1 or 50, comprising screen means.

54. The device of any one of claims 1 or 50 to 53, comprising absorptive screen means.

55. An imaging device as claimed in claim 1 or claim 2 and substantially according to any embodiment hereinbefore described.

56. An imaging device substantially as hereinbefore described, with reference to and illustrated in the accompanying drawings.

57. A louvre with at least one side made retro-reflecting.

58. A beam splitter comprising a sheet of transparent material coated with an intermittent specularly reflective coating.

59. A splitter as claimed in claim 58, in which the reflecting coating has a light-absorptive backing.



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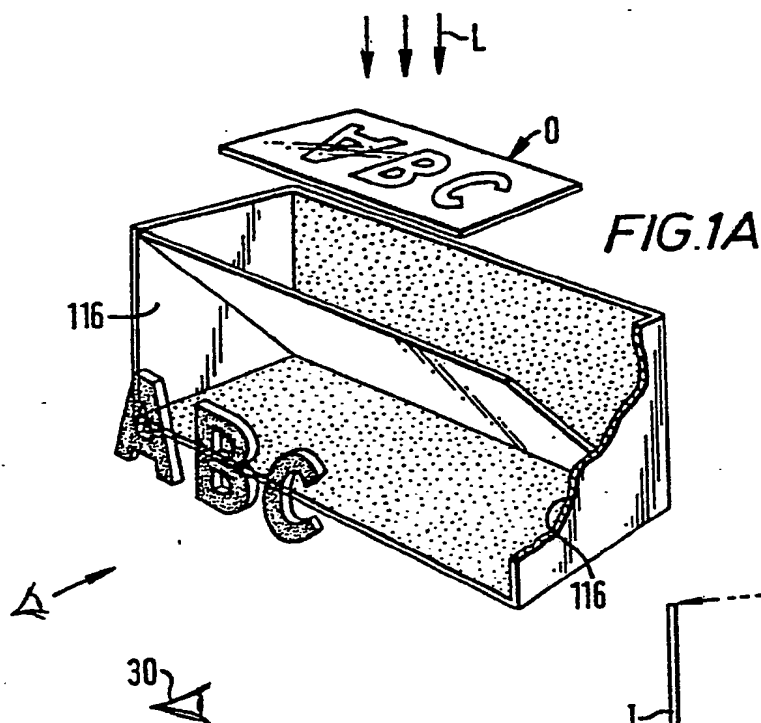
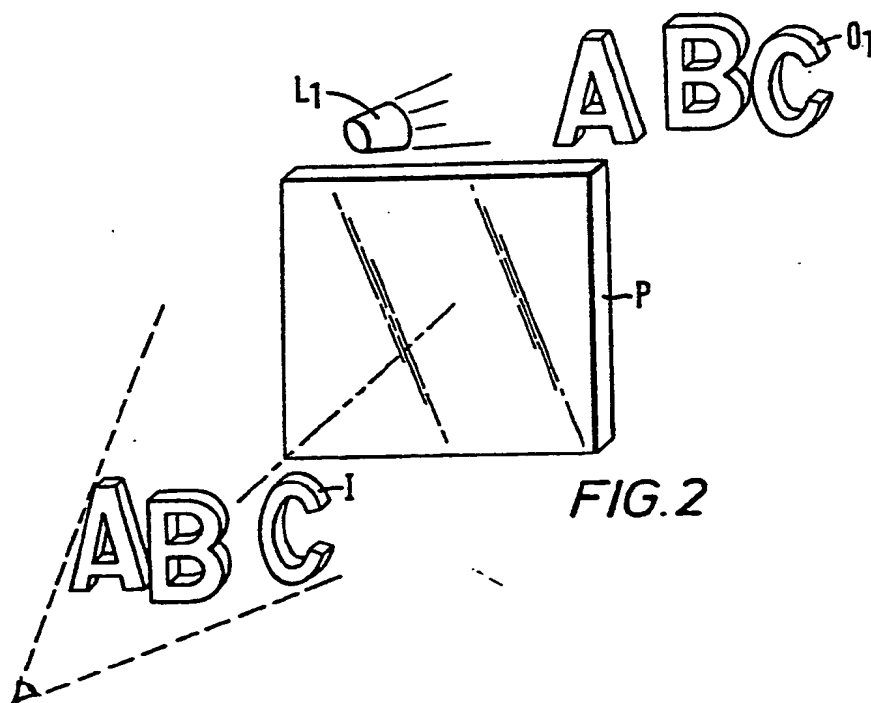
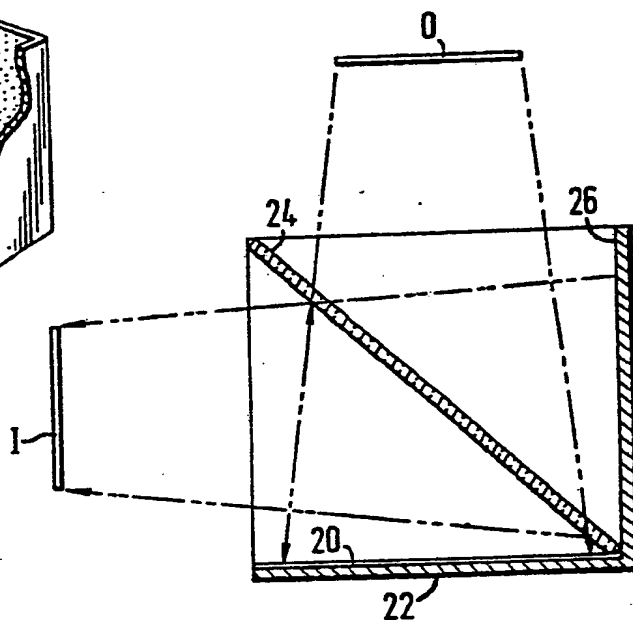


FIG. 1B



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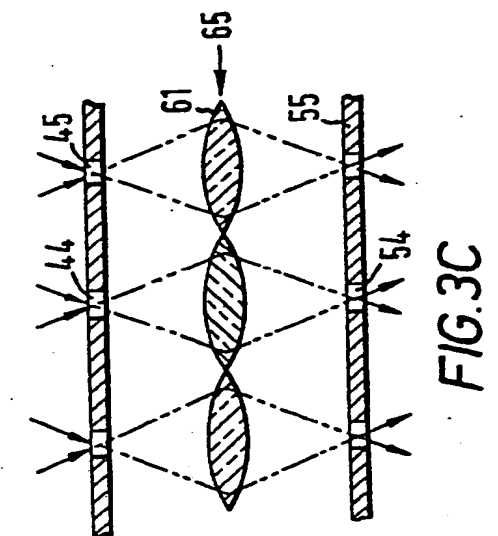


FIG. 3A

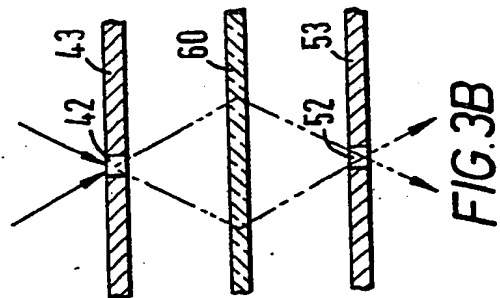


FIG. 3B

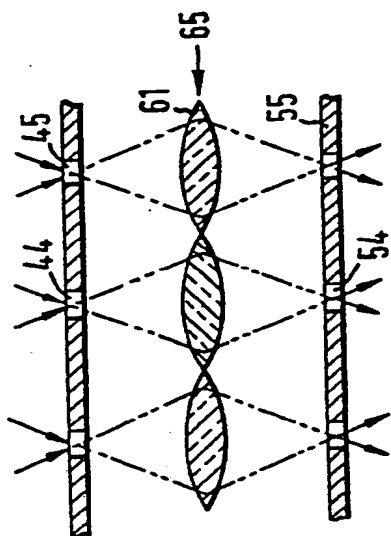


FIG. 3C

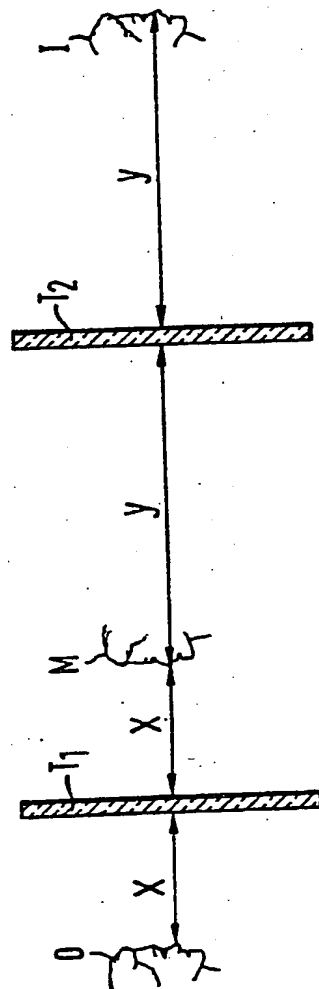


FIG. 4

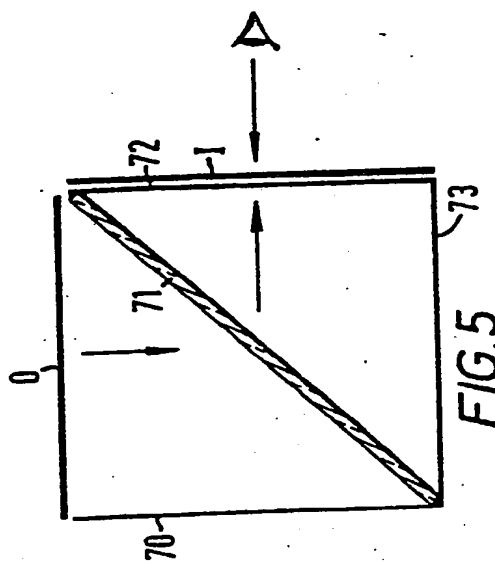


FIG. 5

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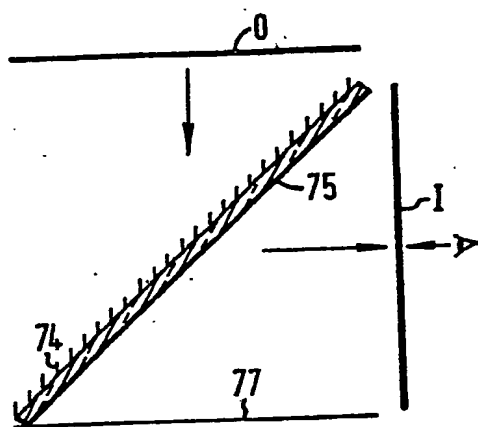


FIG. 6A

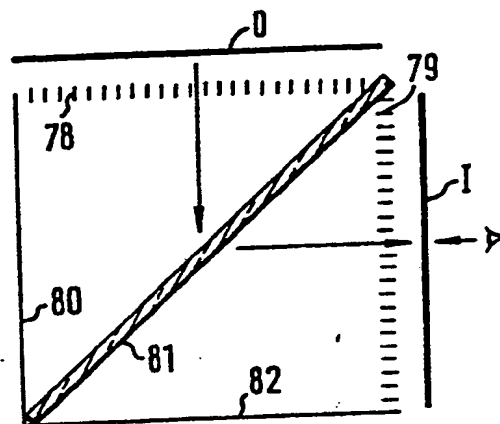


FIG. 6B

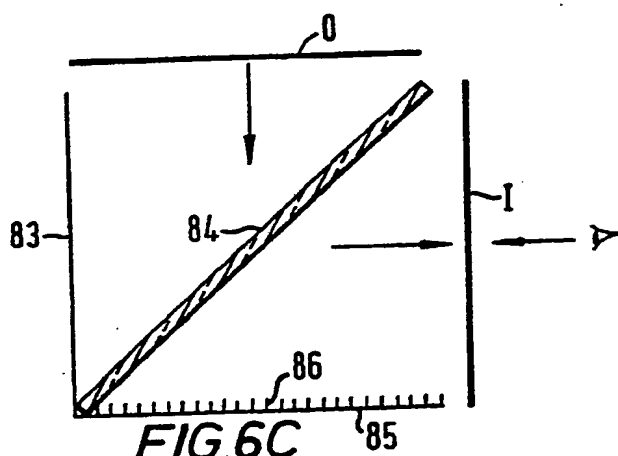


FIG. 6C

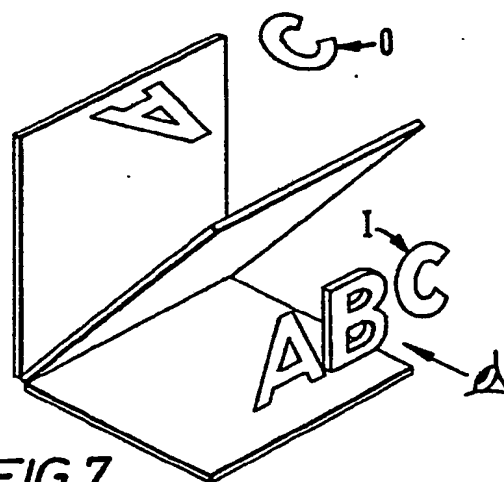


FIG. 7

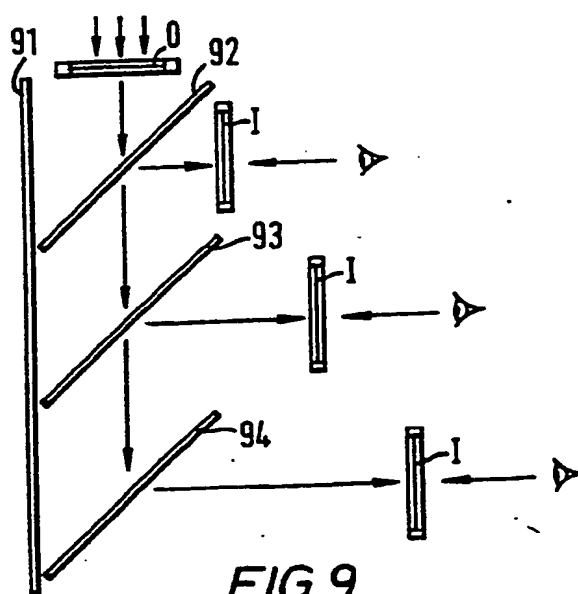


FIG.9

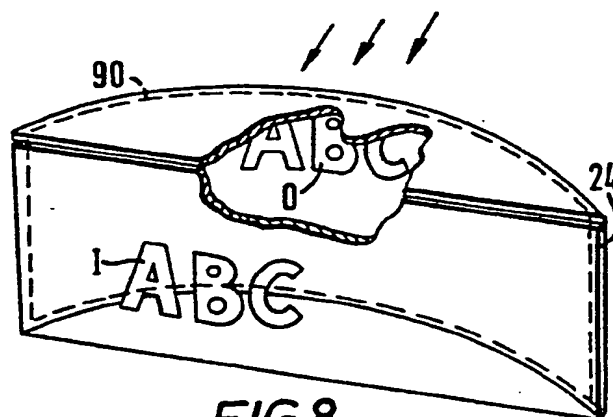
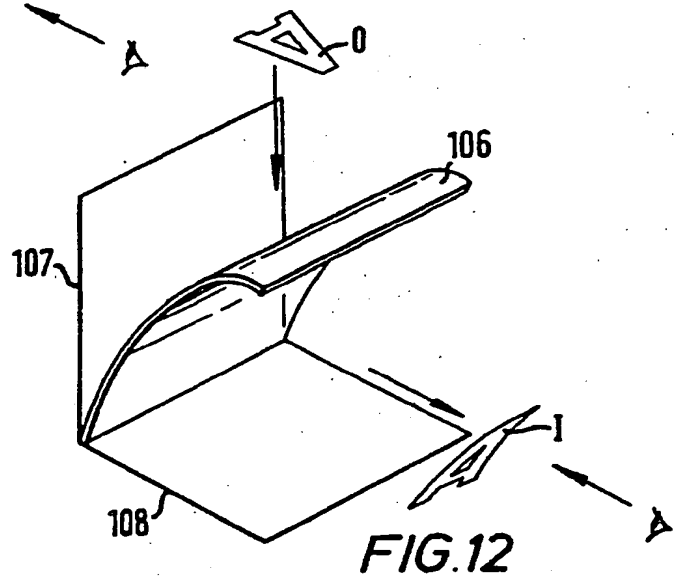
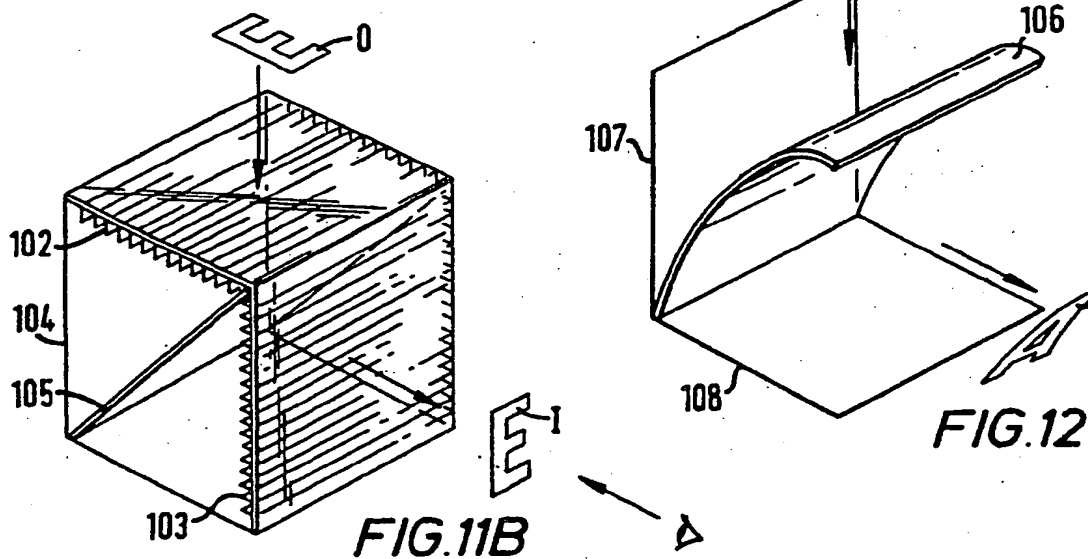
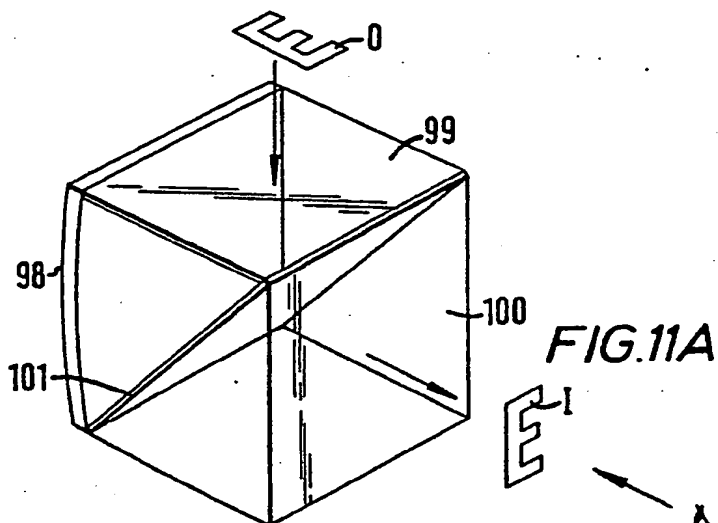
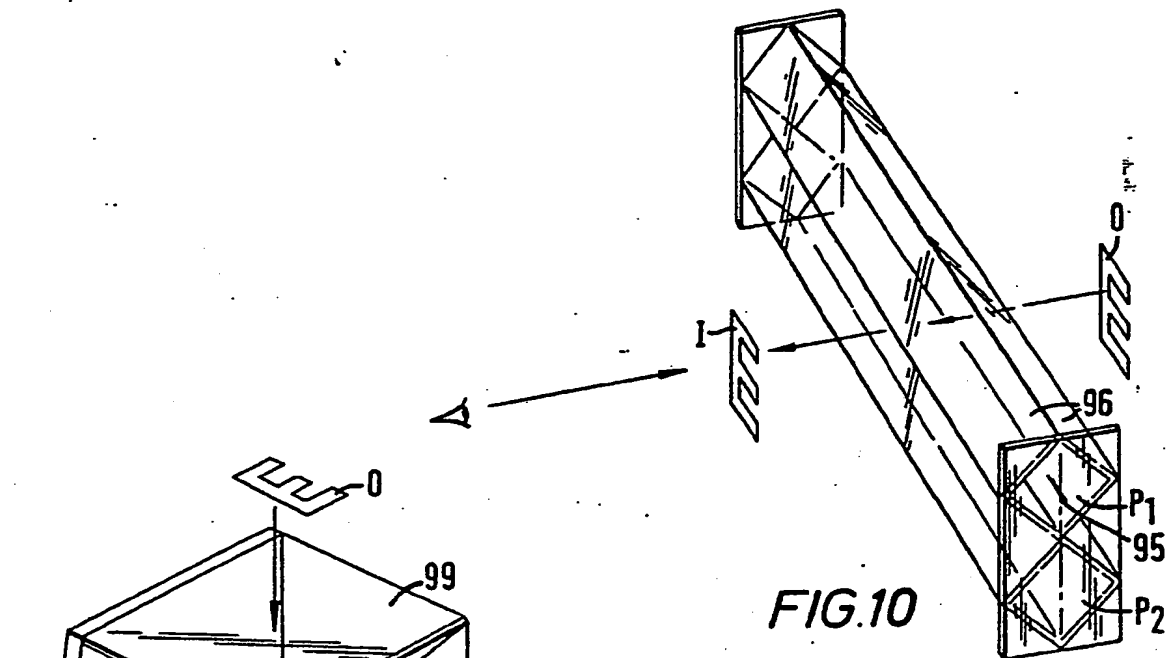


FIG.8

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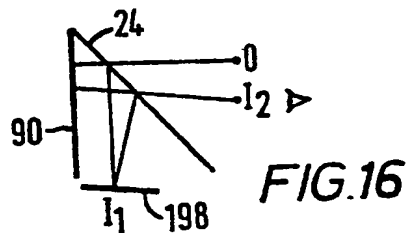
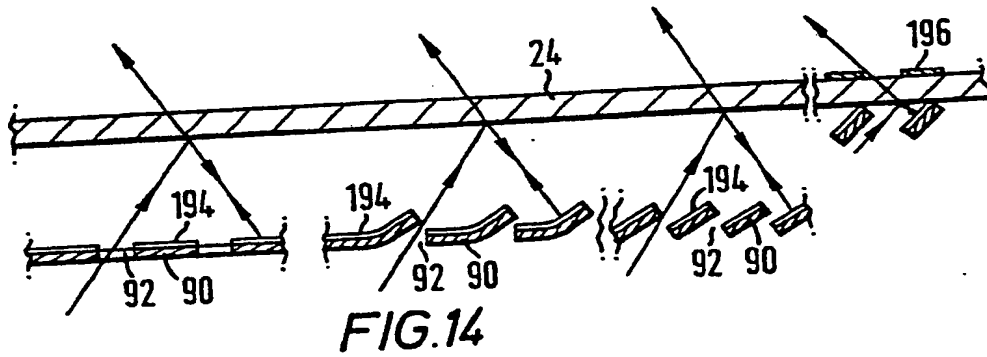
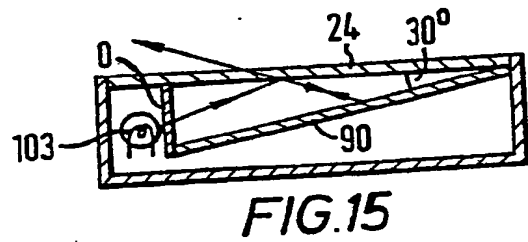
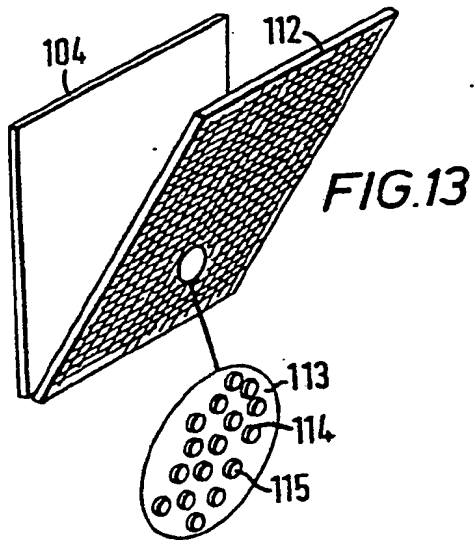
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INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 83/00044

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) ¹ According to International Patent Classification (IPC) or to both National Classification and IPC IPC ³ : G 09 F 19/12; G 09 F 13/12; G 03 B 21/00																	
II. FIELDS SEARCHED <div style="text-align: right; font-size: small;">Minimum Documentation Searched ⁴</div> <table style="width: 100%; border: none;"> <tr> <td style="width: 20%; border: none;">Classification System</td> <td style="border: none;">Classification Symbols</td> </tr> <tr> <td style="border: 1px solid black; padding: 5px;">IPC³</td> <td style="border: 1px solid black; padding: 5px;">G 09 F; G 03 B; G 02 B</td> </tr> </table> <div style="text-align: center; font-size: x-small; margin-top: 5px;">Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁵</div>			Classification System	Classification Symbols	IPC ³	G 09 F; G 03 B; G 02 B											
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IPC ³	G 09 F; G 03 B; G 02 B																
III. DOCUMENTS CONSIDERED TO BE RELEVANT ¹⁴ <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 10%; font-size: x-small;">Category ⁶</th> <th style="width: 70%; font-size: x-small;">Citation of Document, ¹⁵ with indication, where appropriate, of the relevant passages ¹⁷</th> <th style="width: 20%; font-size: x-small;">Relevant to Claim No. ¹⁸</th> </tr> </thead> <tbody> <tr> <td style="text-align: center; vertical-align: top;">A</td> <td>US, A, 3200702 (AMES F. GIORANO) 17 August 1965 see claim; column 1, lines 41-50; column 2, lines 4-52; figures 1-3 ---</td> <td style="text-align: center; vertical-align: top;">1, 2, 39</td> </tr> <tr> <td style="text-align: center; vertical-align: top;">A</td> <td>GB, A, 768394 (H.A. ALEKAN) 13 February 1957 see claim 1; page 3, lines 34-80; figures 1-3 ---</td> <td style="text-align: center; vertical-align: top;">1, 2, 10, 11</td> </tr> <tr> <td style="text-align: center; vertical-align: top;">A</td> <td>GB, A, 314661 (W.J. BEVILLE) 25 July 1929 see claims 1, 3-7; figures 2-6 ---</td> <td style="text-align: center; vertical-align: top;">5</td> </tr> <tr> <td style="text-align: center; vertical-align: top;">A</td> <td>US, A, 1795126 (E. HIGGINS) 3 March 1931 see claim 2; page 1, lines 62-75; figures 1-3 -----</td> <td style="text-align: center; vertical-align: top;">4</td> </tr> </tbody> </table>			Category ⁶	Citation of Document, ¹⁵ with indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No. ¹⁸	A	US, A, 3200702 (AMES F. GIORANO) 17 August 1965 see claim; column 1, lines 41-50; column 2, lines 4-52; figures 1-3 ---	1, 2, 39	A	GB, A, 768394 (H.A. ALEKAN) 13 February 1957 see claim 1; page 3, lines 34-80; figures 1-3 ---	1, 2, 10, 11	A	GB, A, 314661 (W.J. BEVILLE) 25 July 1929 see claims 1, 3-7; figures 2-6 ---	5	A	US, A, 1795126 (E. HIGGINS) 3 March 1931 see claim 2; page 1, lines 62-75; figures 1-3 -----	4
Category ⁶	Citation of Document, ¹⁵ with indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No. ¹⁸															
A	US, A, 3200702 (AMES F. GIORANO) 17 August 1965 see claim; column 1, lines 41-50; column 2, lines 4-52; figures 1-3 ---	1, 2, 39															
A	GB, A, 768394 (H.A. ALEKAN) 13 February 1957 see claim 1; page 3, lines 34-80; figures 1-3 ---	1, 2, 10, 11															
A	GB, A, 314661 (W.J. BEVILLE) 25 July 1929 see claims 1, 3-7; figures 2-6 ---	5															
A	US, A, 1795126 (E. HIGGINS) 3 March 1931 see claim 2; page 1, lines 62-75; figures 1-3 -----	4															
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IV. CERTIFICATION <table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border: none;"> Date of the Actual Completion of the International Search ¹⁹ <div style="text-align: center; font-size: large;">27th June 1983</div> </td> <td style="width: 50%; border: none;"> Date of Mailing of this International Search Report ² <div style="text-align: center; font-size: large;">27 JUNE 1983</div> </td> </tr> <tr> <td style="width: 50%; border: none;"> International Searching Authority ¹ <div style="text-align: center; font-size: large;">EUROPEAN PATENT OFFICE</div> </td> <td style="width: 50%; border: none;"> Signature of Authorized Officer ²⁰ <div style="text-align: center; font-size: large;">G.L.M. Kruydenberg</div> </td> </tr> </table>			Date of the Actual Completion of the International Search ¹⁹ <div style="text-align: center; font-size: large;">27th June 1983</div>	Date of Mailing of this International Search Report ² <div style="text-align: center; font-size: large;">27 JUNE 1983</div>	International Searching Authority ¹ <div style="text-align: center; font-size: large;">EUROPEAN PATENT OFFICE</div>	Signature of Authorized Officer ²⁰ <div style="text-align: center; font-size: large;">G.L.M. Kruydenberg</div>											
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ANNEX TO THE INTERNATIONAL SEARCH REPORT ON

INTERNATIONAL APPLICATION NO.

PCT/GB 83/00044 (SA 4830)

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A- 3200702		None	
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GB-A- 768394		None	
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GB-A- 314661		None	
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US-A- 1795126		None	
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